

THE FUTURE OF ENGINEERING EDUCATION

Johns Hopkins University, November 20, 1999

It is an honor to be invited to participate in the celebration of an important milestone for engineering here at the nation's very first research university. Johns Hopkins University blazed a trail for the development of the modern research university, and it continues to serve a leader among the nation's institutions of higher education.

My personal connection to the G.W.C. Whiting School of Engineering, in addition to sharing its initials, is through your own distinguished Professor Charles O'Melia, who, in a former life as a professor at Georgia Tech long ago, had to contend with me as a student in his class. I am sure that Charlie thought he was rid of me after I left his class, but I keep bouncing up on his radar screen like bad penny. Seriously, Charlie was a superb instructor and, although I did not know it at the time, was one of the first who demonstrated for me how a faculty involved in

research brought new insight and vitality to the classroom and its learning environment.

Looking back, I was fortunate to have been taught engineering, first at Georgia Tech, and later at U.C. Berkeley, by many faculty who were committed to the learning process while engaged in high level research. As I speak today to the future of engineering education, the opportunity for a student to learn from a faculty member who is engaged in research and the creation of knowledge, and who can bring this excitement to the classroom, is one of the bedrock values that deserves preservation in the face of the turmoil of our rapidly changing world. But it won't be easy, and it probably won't be accomplished in the same way.

The future of engineering education is a topic of considerable importance to our nation, our educational institutions and of consequence to me personally. As an engineer, I am concerned about my profession. As an engineering educator of some 30 years, I have a vested interest in insuring the opportunities that I experienced are

available to other generations to come. As the president of a university that graduates the largest numbers of engineers in the nation, I feel a heavy responsibility for the more than 2,000 engineering graduates that leave Georgia Tech each year and the growing number of engineers who return to us for skills renewal.

Now, it is always dangerous to talk about the future of anything. I think of T.J. Watson who founded IBM. (SLIDE: Predicting Future) When computers were first created, he predicted that we might need about six of them. As recently as 1977, Ken Olsen, the founder of Digital Equipment Corporation, believed that none of us would ever have a computer in our homes. These men were leaders and experts in their fields, and they still got it wrong. So I am a little reluctant to make specific pronouncements about the future of engineering education.

But I believe we are at a critical moment in the life of engineering education, and I want to look with you at some of the forces at large in

the world today that will shape the look of engineering education in the future.

To begin, we have to appreciate that many prestigious and thoughtful groups have studied and opined about the future of engineering education. They have correctly told us that the world of engineering work has changed and we should focus more effort on team-based learning, problems with open-ended solutions, additional hands-on projects, and communications. In the past decade we have made progress towards these objectives, but in my view we have limited the potential of our efforts by working within the constraints of two tacit assumptions. (SLIDE: Assumption #1)

The first is that the university within which engineering is taught is a static entity that has its full focus on a pure educational mission. In an ideal world this would be true, but today's university is a complex organization whose attention span has been shortened by dealing with conflicting pressures from the political realm, financial issues,

technological challenges, and emerging new competition. (SLIDE: Chambers Quote)

As recently as Wednesday of this week, the *New York Times* quoted John Chambers, CEO of the technology star, Cisco Systems, who predicts that education will overshadow e-mail as the next killer application for the Internet. So, as we think about engineering education and what we might do about it, remember that the parent organization within which it fits is no longer a contemplative place with ivy covered walls, but a moving target. Providing a “fix” for engineering education in today’s university is like trying to perform open heart surgery on a marathon runner during the race. (SLIDE: Assumption #2)

The second confining assumption that is often made is to view engineering education as the sum of its curricular parts. We teach engineering theory, design and, hopefully, also some elements of practice. We require students to study the essential math and sciences that form the knowledge base for our profession. And our students take

the humanities and social science courses that comprise the core of any higher education curriculum.

Past discussions of engineering education have largely focused on how to squeeze an adequate amount of each of these ingredients into the four-year time framework of the conventional bachelor's degree program. And the goal of the discussion is usually to negotiate an acceptable compromise among the champions of these various elements.

But when you step back and look at the larger picture, the perspective changes dramatically. We must understand that we limit our horizons by hoping the university will pay attention to our particular professional problems and by arguing about shifting a few credit hours here or there.

For our purposes today, I'd like to look back to Washington Irving's famous story about Rip Van Winkle. If you remember, Rip inadvertently slept for 20 years, and when he awoke, things had changed

so much that he did not recognize his hometown and had no idea how to fit into this new society. (SLIDE: Rip Quote)

The story of Rip Van Winkle was an allegory for the dramatic change brought about by the industrial revolution. Today we are in the midst of a technology revolution that is even larger and more dramatic in its sweep than the industrial revolution. Its impact on the university and its component parts, engineering education among them, is substantial. And the pace of change is so fast that you don't need to sleep for 20 years to feel like you don't know what's happening. By the time we feel like we are beginning to understand the present, it is already disappearing. (SLIDE: Duderstadt Quote)

Rapid change is particularly disorienting for higher education, because we tend to be tradition bound. Yes, the chalkboard gradually gave way to the dry marker board, and after 30 years in the bowling alley, the overhead projector finally made it into the classroom. But on the whole,

professors have continued to function pretty much the same as
professors have always functioned for decades, even for centuries.

Like Rip Van Winkle, higher education is awaking today to find itself in
a much different environment... an environmental that is more market-
driven and more competitive than in the past. There is a disconnect
between higher education and the workplace. (SLIDE: Restless
Customers)

Both of higher education's traditional customers – its students and their
prospective employers – are making new demands. The equation is
being further changed by the growing need for hundreds of thousands of
workers to update their skills. We have talked a good game about life-
long learning for some time, but the subject is now staring us in the face.
Access to quality engineering education for both traditional and
nontraditional students has to be an issue for all of us. If we don't do
something about it, someone else will.

Our traditional market has been the high school graduate. Today these young people have grown up playing computer and video games. They have learned computer programming in summer camps. They parallel process and play games in which they can change the ending based on how the game is played. (SLIDE: prgmng)

These students use technology to the max. And we are seeing our traditional market change as bright, young, technology-savvy students opt out of completing their college degrees, or in some cases even skip the whole college experience. And, employers are paying them handsomely for skills they have earned outside mainstream education.

The talent war has become so fierce in the information technology industry that they have even begun to recruit high school students. The *New York Times* recently quoted an executive who said, "It doesn't matter if they have a high school diploma or a college degree. It just depends on whether they have the skill sets and the experience."

(SLIDE: Drucker Quote)

Drucker
Quote

This situation, among others, led management consultant Peter Drucker to predict the near term demise of brick and mortar institutions. If we want his prediction to suffer the same fate as T.J. Watson's and Ken Olsen's, we cannot sit idly by and expect the world to continue to beat a path to our door. (SLIDE: Future of Eng Ed)

So, the future of engineering education goes beyond the question of how to juggle disciplinary ingredients. It becomes a question of how teaching and learning will occur in an era of revolutionary new information technology and a fast-paced economy in which the university as an institution must think about its own survival strategy.

Fortunately, every time of challenge is also a time of opportunity. This new age of technology has created a tremendous demand for engineers, and most employers want someone who has a full degree experience. It has the potential to be an exciting time for engineering education, with

significant opportunities to make the teaching of engineering practice more interesting than ever before. (SLIDE: Our Challenge)

Our challenge is to make engineering education relevant, to reflect the new business world of venture capital and startups, to use technology to enhance learning and improve access, and to engage our engineering faculties and programs in helping our universities reshape their role in society and remain relevant.

To paraphrase that great philosopher Wayne Gretsky, if we skate to where the puck is now, we will be too late. We need to skate to where the puck will be. (SLIDE: Interdisciplinary Skills)

I would begin by stressing the importance of building innovative interdisciplinary approaches to the issues the university needs to help society address. Engineering faculty and our educational processes need to move outside traditional disciplinary restraints to engage colleagues in

business, policy, science and architecture in creating the skill sets needed for the future. This means both in research and in the curriculum.

An elegant example is what we need to do to help preserve the environment for future generations. No task is more important than this, and our universities need to be at the forefront of the effort. Yet even today, many universities have compartmentalized their environmental efforts into specialty areas within engineering or science, and the two are often at odds. We are often still wedded to the notion that environmental preservation and economic development are opposites – that you have to choose one and do it at the expense of the other. And it is true that the global industrialization and new technologies of the 20th century have helped to stretch the capacities of our finite natural system to precarious levels.

But engineering and its technological derivatives can also help to remedy the problem. (SLIDE: Sustainability Quote) The well-being of future generations depends on a new breed of engineer who will develop

and use the sustainable technology and the benign manufacturing processes that will simultaneously support a healthy economy and a healthy environment.

As we attempt to educate that new breed of engineers, our goal should not be to create a new academic major or degree, but rather to approach all of engineering education from a sustainability perspective, so that all the engineers we graduate are sensitive to the impact of their decisions on the natural environment. (SLIDE: New Economy)

A second major force underway in the world at large that must permeate the mindset of engineering education is the entrepreneurism that is driving the new economy. The pace of technological innovation has become incredibly rapid, which creates openings for something or someone new to get a foot in the door. As a result, the economy has become entrepreneurial. It is exciting, and our students are gravitating toward it, but not much in the engineering education curriculum today reflects this development.

When I was an undergraduate at Georgia Tech three decades ago, my fellow students used to discuss which large corporation they would work for and what the pension plan looked like. Today, we have to help our students envision themselves as entrepreneurs running successful start-up companies.

Further, all of today's industries, not just the new start-ups, must be nimble and creative to survive. Hewlett Packard reports that 60% of their sales today come from products introduced in only the last two years. Innovation and time to market are crucial, so even the largest corporations are looking for engineers who think like entrepreneurs. In addition to being technically competent, engineers must also be creative in problem-solving, perceptive about the global economy, knowledgeable about management and able to communicate their ideas effectively.

Engineers are naturals for this entrepreneurial culture, but to prepare them and to show engineering's link to it, we need to work with faculty in business management and related fields to help our graduates develop the broader range of skills that they will need. (SLIDE: Info Tech)

Information technology is a third agent of change in my list, not only because of the new economic ventures it has generated, but also because it is influencing the way engineers do business and the future of the teaching and learning environment. The Boeing 777 is a good case study of how information technology is revolutionizing engineering practice. This airplane is one of the world's largest and most complex machines. It has 132,500 uniquely engineered parts that were designed in 12 different nations. In the United States alone, 487 suppliers made parts for it. Yet no full-scale mock-up of the plane was ever made to make sure all the parts would fit together. It was simply built and flown. (SLIDE: Vest Quote)

What made it work was a team process that brought together representatives from design, analysis, manufacturing, tooling, materials and customer service – plus vendors and customers. The design of the parts was coordinated across company lines and national boundaries using compatible software on network computers. Three-dimensional parts and systems were electronically assembled and tested on workstation display screens.

This kind of multi-disciplinary collaboration through technology will soon characterize the world in which our students will work. And they need to know how to work with diverse partners on electronically connected teams that span a global economy. (SLIDE: University: IT)

The parallel to the use of technology for collaborative design in industry is its use in delivery of education and to assist in learning. Computer usage by individuals has been pervasive at universities for more than a decade, and many universities have begun to use telecommunications technology to deliver distance learning courses. But it is the near

revolutionary expansion of the Internet that is awakening us, specifically the development of virtual universities. And if John Chambers is correct, the biggest jolt for education is still to come.

If you take Georgia Tech as an example, you can see the power of the changes, and this is just the tip of the iceberg. In the past five years, we have installed 1,700 miles of fiber-optic wiring on our campus, and we are developing a pervasive wireless communications network as well. We require all students to own computers that meet specified standards. 280 of our courses incorporate web-based activities, and we have created Classroom 2000, where the notes the professor writes on the board appear like magic on the screens of the students' computers.

With the help of Hewlett Packard, Intel and Texas Instruments among others, our School of Electrical and Computer Engineering is remaking its undergraduate curriculum under the theme, "Digital First," with the goal of having a fully computer/Internet based delivery by the year 2001.

This year we began to offer a master's degree in mechanical engineering over the Internet, a degree program that was developed with the help of the Sloan Foundation specifically for Internet delivery. We will bring two more Internet master's degrees on-line within the next year or so.

Our objective is not to use technology for technology's sake, but to use its power to free faculty members for increased interaction with their students, and to create greater access to information while improving the learning process. We also expect this technology will help us address the needs of our nontraditional students who are seeking continuing education, by delivering it to them on at their jobs or their homes. All of this development, which is in full support of the institutional goals of Georgia Tech and engineering, is helping us prepare to avoid the dismal fate Peter Drucker predicted for brick and mortar universities.

There are of course many questions about education technology. Are all of these measures going to be effective? Will students learn more and

better? These questions and others deserve careful study, and we will continue to put ourselves to the test, but we cannot stand by warming up on the sidelines of a race that is already underway.

The trends towards things interdisciplinary, entrepreneurial, and information technology-based represent departures from what we have done before. (SLIDE: Practice of Eng) However, the future of engineering education also has to recognize a fourth agent, one that is not so new, but which is needed more than ever before in today's fast paced world. And, one that we have neglected in recent times. That is, the importance of instilling in our graduates an understanding of what it means to practice engineering. Many of the pieces I have already mentioned relate to the practice of engineering in our modern world, but the essence of engineering practice is more than this. In my connotation, engineering practice involves the ability to compromise within time constraints, to define the problem rather than having it handed to you, and to deal with political pressures. It involves an appreciation of ethics and an understanding of one's civic obligations.

(SLIDE: Bordogna Quote)

The umbrella of engineering practice is also a powerful incubator for success for the large number of our graduates who leave the profession for other pursuits. This dimension of engineering education is important as we recognize that the growing dependency of society on technology will inevitably result in many of our graduates being called upon to be leaders of their businesses and communities in the future.

The teaching of the practice of engineering is not something easily done and not all faculty are able to do it, particularly at the beginning of their careers. Indeed, it is unrealistic to expect all faculty to come with recent, hands-on experience in engineering practice. But it is our responsibility to have enough faculty with the requisite experience to teach well-designed capstone courses that draw together the threads of a student's education and apply them to practical projects. These projects should challenge our students in as many aspects of engineering practice as possible and enable a rich discourse to occur with the faculty member as the solutions are worked out.

Over time, senior faculty must help mentor young faculty and help them on the path towards learning what engineering practice is so they, in their turn, can teach it. To insure we have built the appropriate infrastructure, each engineering department should annually assess itself to see that it is working as a unit in such a way as to impart what it means to practice engineering to its graduates.

So I have made the case for four of the challenges facing engineering educators. Each is important, and it is my opinion we can best address them if we come from the view of the larger perspective and that of the universities within which we work. (SLIDE: Future of Eng Ed)

Now, if you have been listening patiently in anticipation of the silver bullet in this talk, I am going to let you down right now and tell you that there is none. There is no easy answer, and no magic ingredient that will work the same for each institution.

The good news is that our future lies in our hands, and it is one of opportunity – opportunity to become involved with the entrepreneurial business world; opportunity to be more resourceful in our use of technology in the education process; opportunity to infuse our curriculum with the concepts like sustainable technology; opportunity to prepare our students for the leadership responsibilities they will face; and the opportunity to help our universities renew their value to society.

(SLIDE: Pogo Quote)